NPOESS Orbit: Mean Local Time of Ascending Node vs. Spacecraft Time in Shadow

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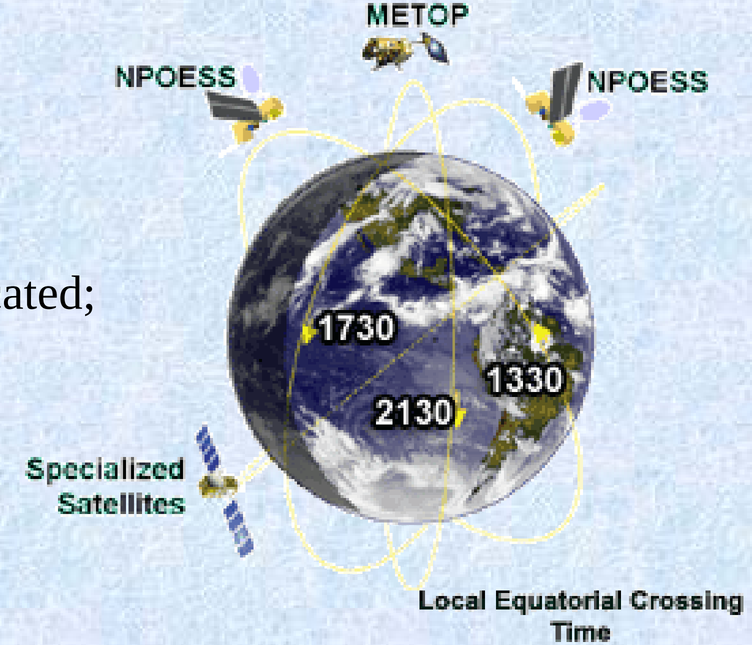
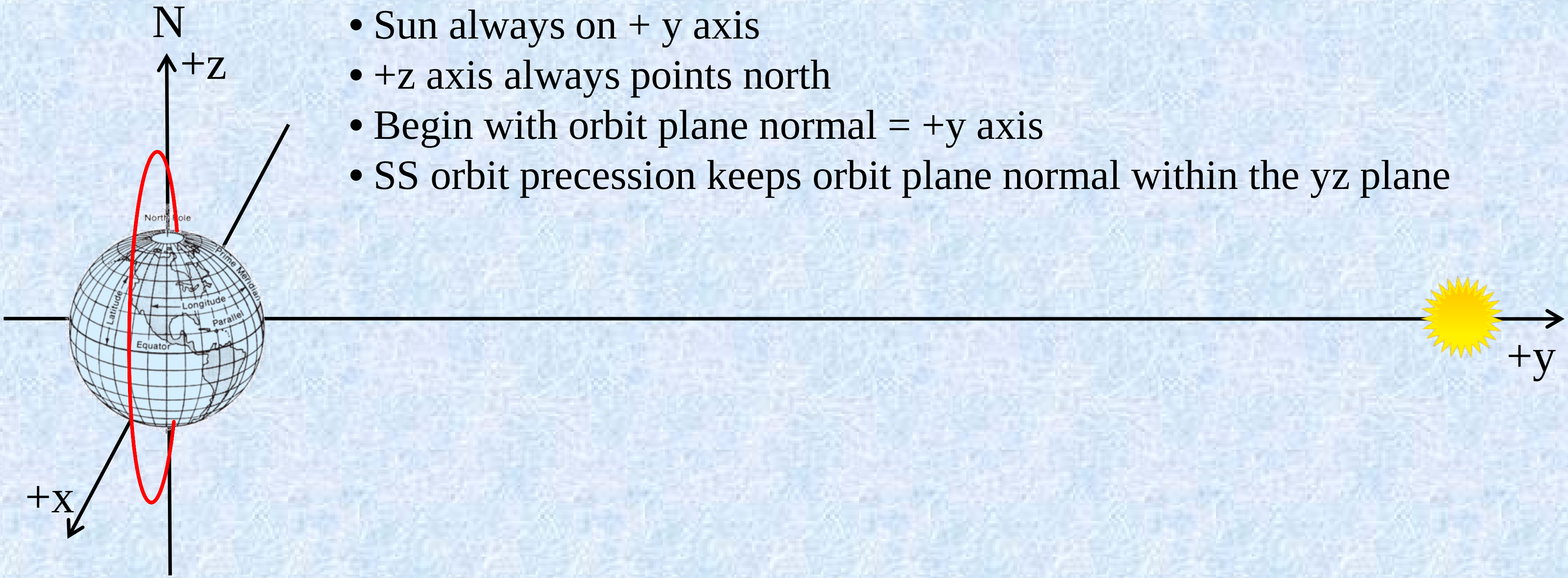
Motivation

- Customers for wind mission are NASA, **IPO/NPOESS**, and DOD
- NPOESS orbit height is 824 km
- NPOESS mean local time of ascending node (MLTAN) (local time when crossing equator from south to north) either or 1330 (C-1, C-3) (afternoon), or 1730 (C-2, C-4) (morning) [inclination angle = 97.727 deg]
- Active remote sensors need power, hence sunlight; hence sun-synchronous orbit
- Can Doppler lidar work with any node time?
- Typical orbit software is very expensive and complicated; includes rigorous position vs. time
- We only need time in shadow



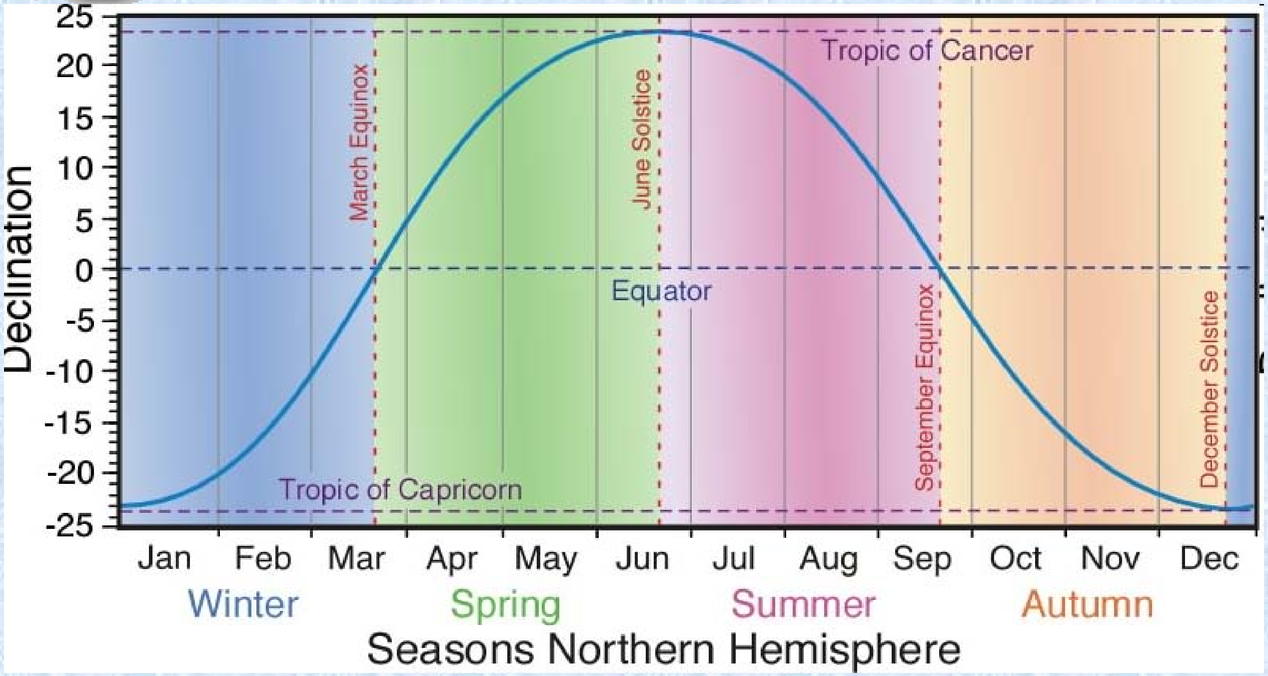
Simplified Approach in MS Excel

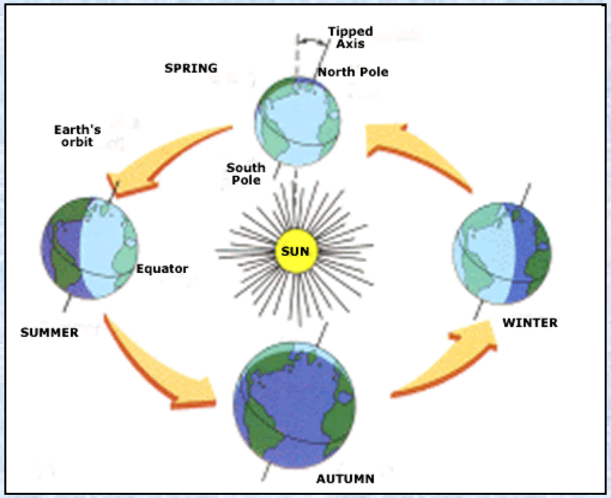
- Neglect earth rotation, local time, and local position
- Sun always on + y axis
- +z axis always points north
- Begin with orbit plane normal = +y axis
- SS orbit precession keeps orbit plane normal within the yz plane

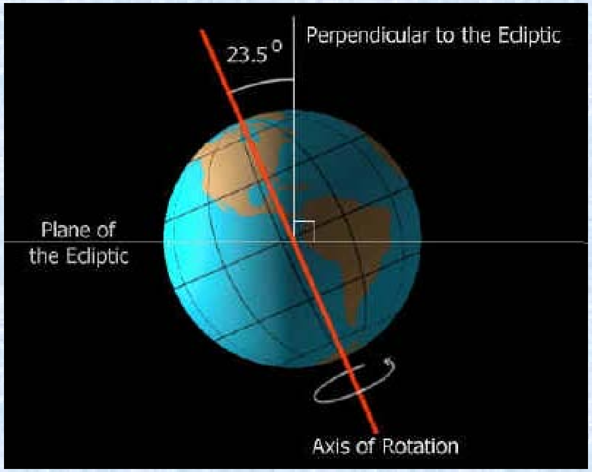


- For inclination angle i, tilt orbit plane about x axis (top of orbit away from sun by i – 90 deg.
- For seasonal tilt, tilt orbit plane <u>instead</u> of earth, about x axis (top of orbit towards sun in summer)
- For mean local time of ascending node, tilt orbit plane about z axis (6 am = normal within yz plane)

Earth Orbit Around Sun







$$\mathrm{Tilt}(m) = 23.5^\circ \cos\left[2\pi\left(\frac{m - 17/3}{12}\right)\right]$$

m = number of months into year

Positive tilt is toward the sun at the north pole

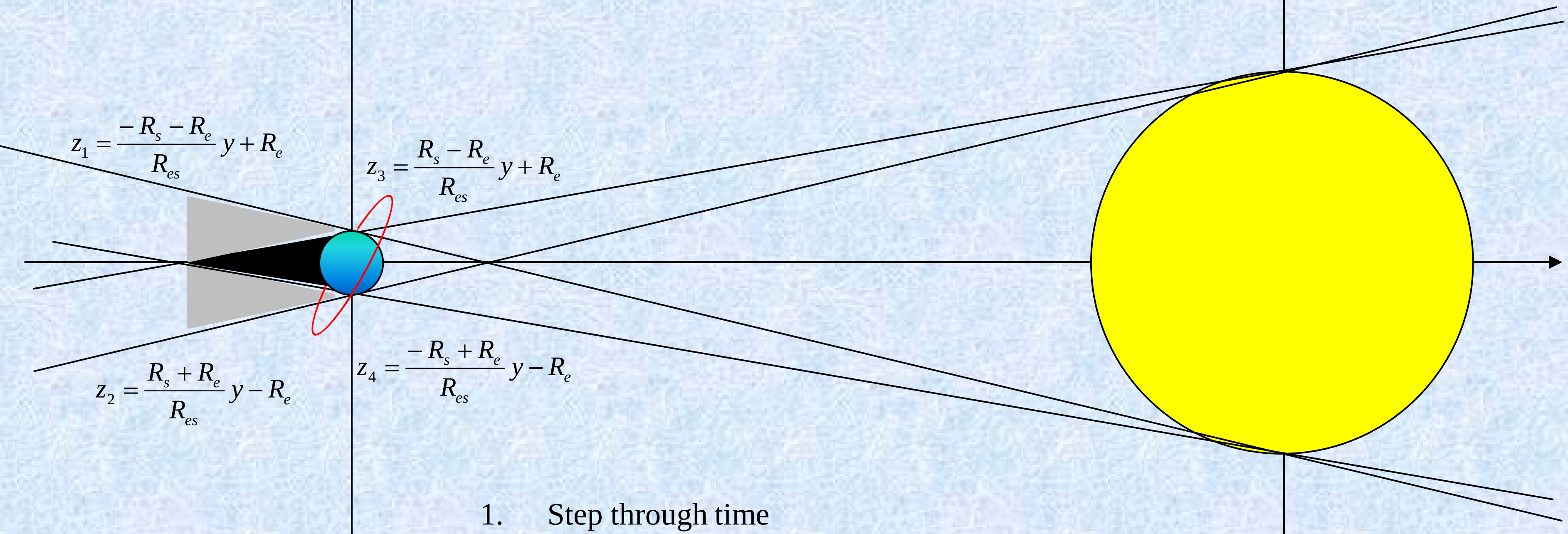
Sunlight, Penumbra, and Shadow

x = 0 plane

D_e = Earth Diameter = 1.2756×10^7 m

$R_e = D_e/2 = 6.378 \times 10^6$ m
$R_s = D_s/2 = 6.96 \times 10^8$ m

D_s = Sun Diameter
$1.392\ \ 10^9$ m
= 109 x earth diam.



$$z_1 = \frac{-R_s - R_e}{R_{es}} y + R_e$$

$$z_2 = \frac{R_s + R_e}{R_{es}} y - R_e$$

$$z_3 = \frac{R_s - R_e}{R_{es}} y + R_e$$

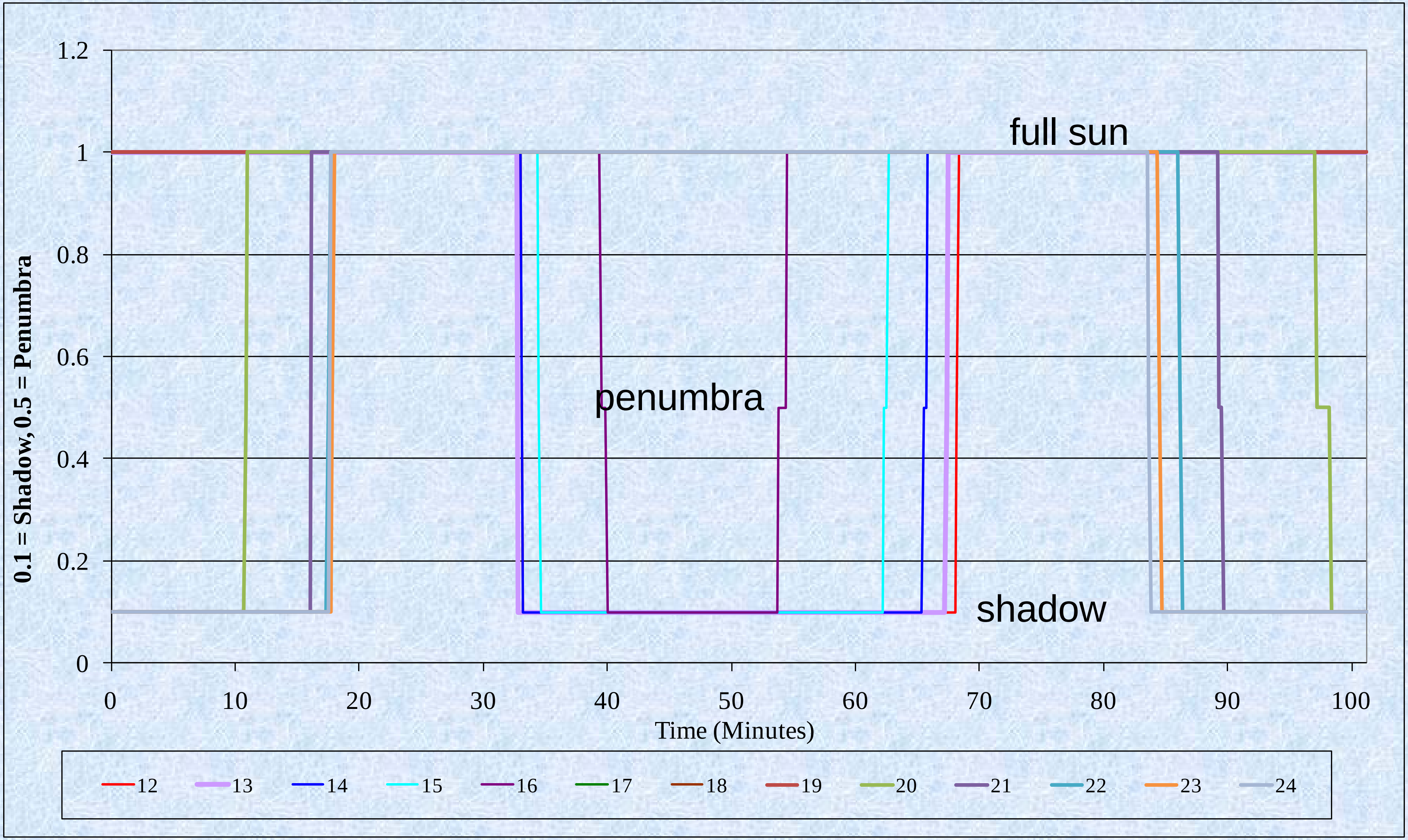
$$z_4 = \frac{-R_s + R_e}{R_{es}} y - R_e$$

y = 0

$y = R_{es} = 1.49597870691 \times 10^{11}$ m

1. Step through time
2. Calculate (x, 0, z) of normal orbit
3. Rotate orbit about x and z axes
4. Look for positions in penumbra and shadow

824 km, +0 deg axis tilt (Sept 21)
Orbit Period = 101.2 minutes
MLT of ascending node = 12:00, 13:00, etc.
Vary MLTAN



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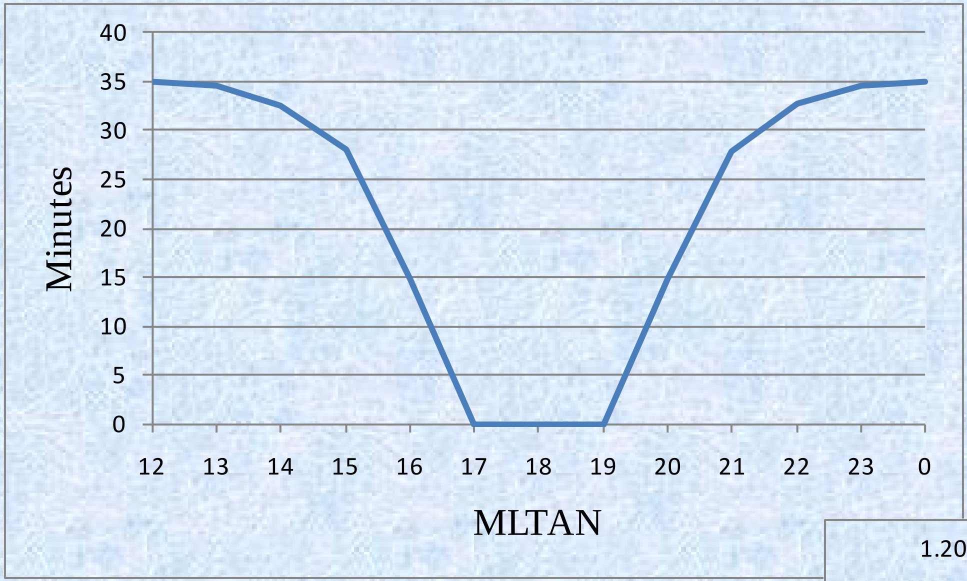
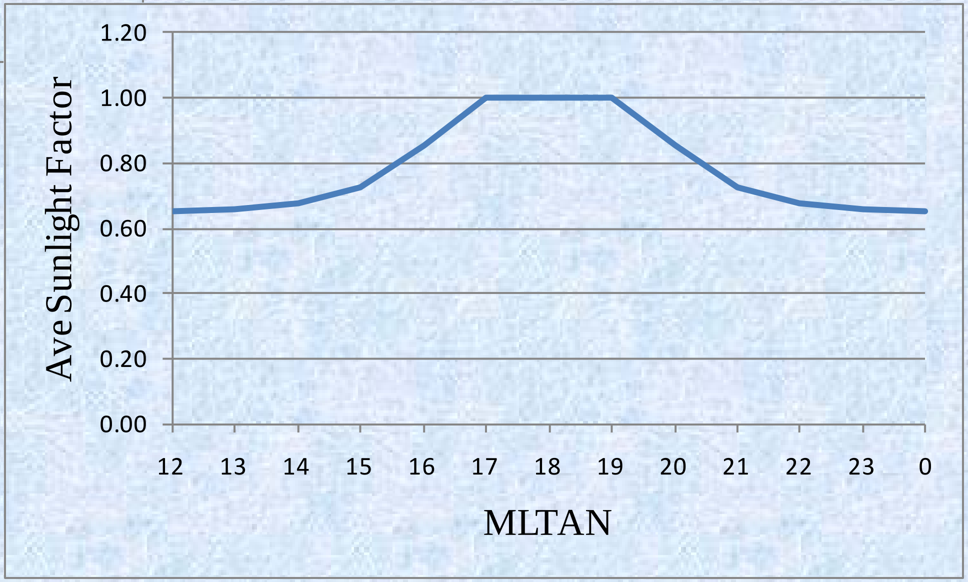


Minimum orbit average

sunlight factor = 0.65

1330 ~ 0.665



NPOESS MLTAN = 1330 or <u>1730</u>

824 km, +23.5 deg axis tilt (June 21)
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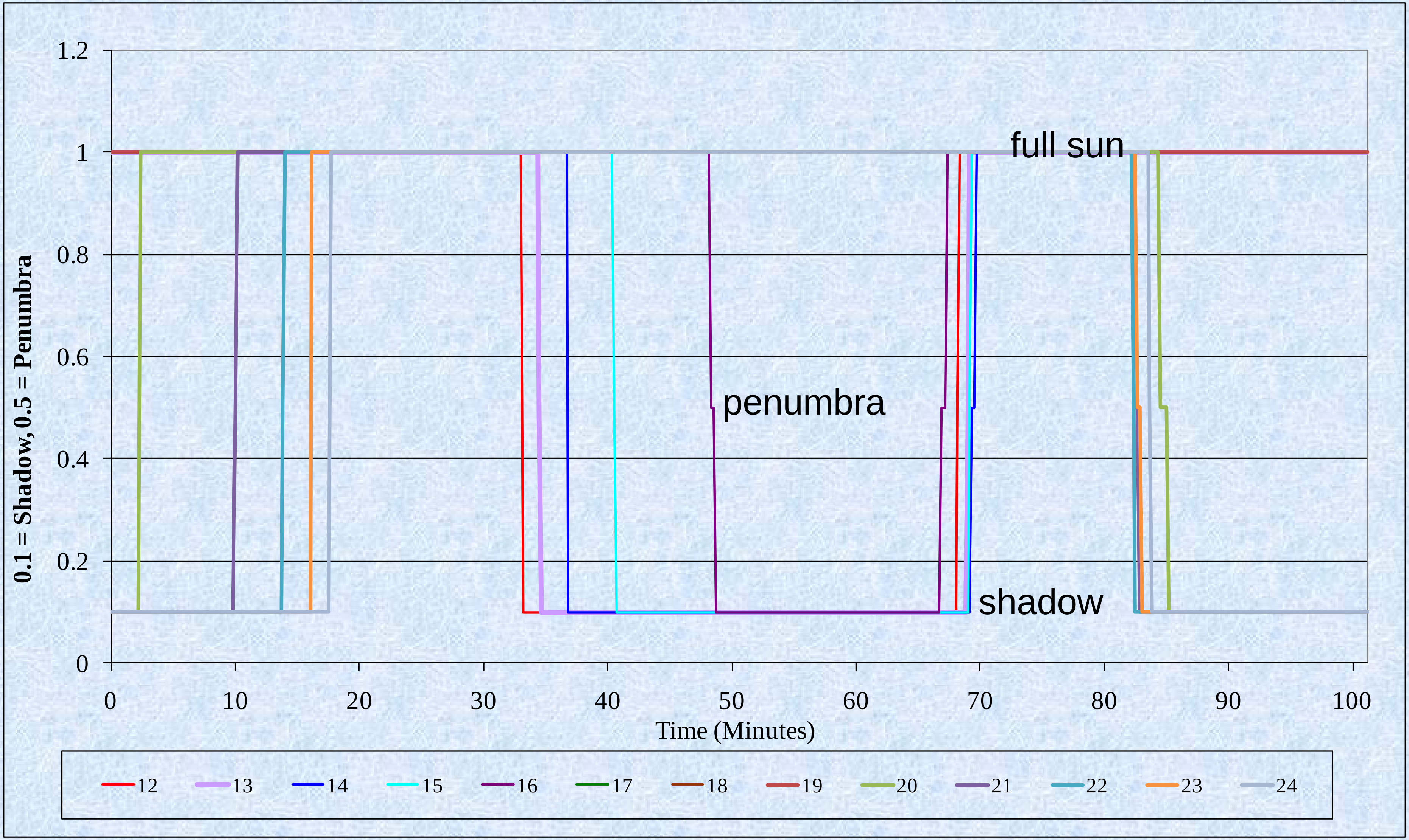
Vary MLTAN



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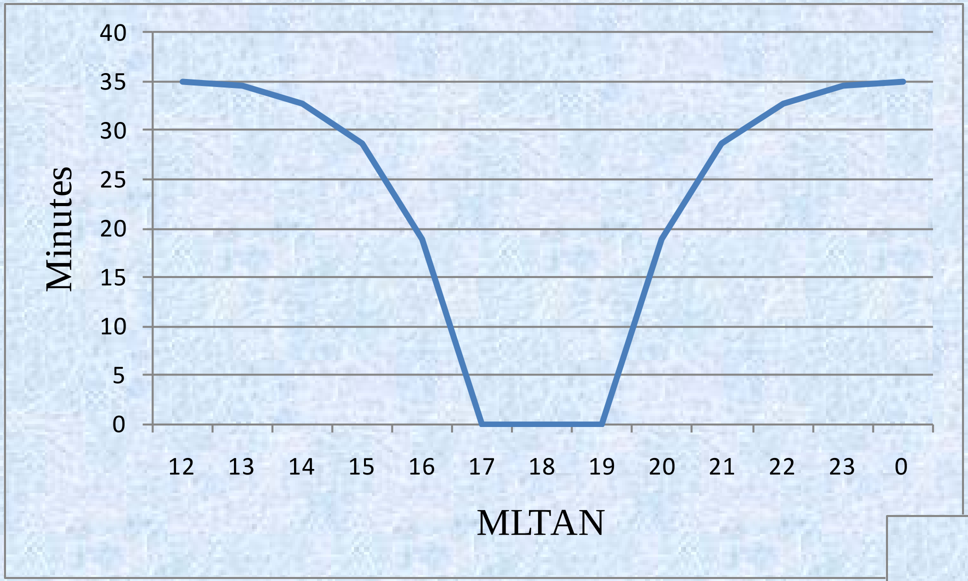
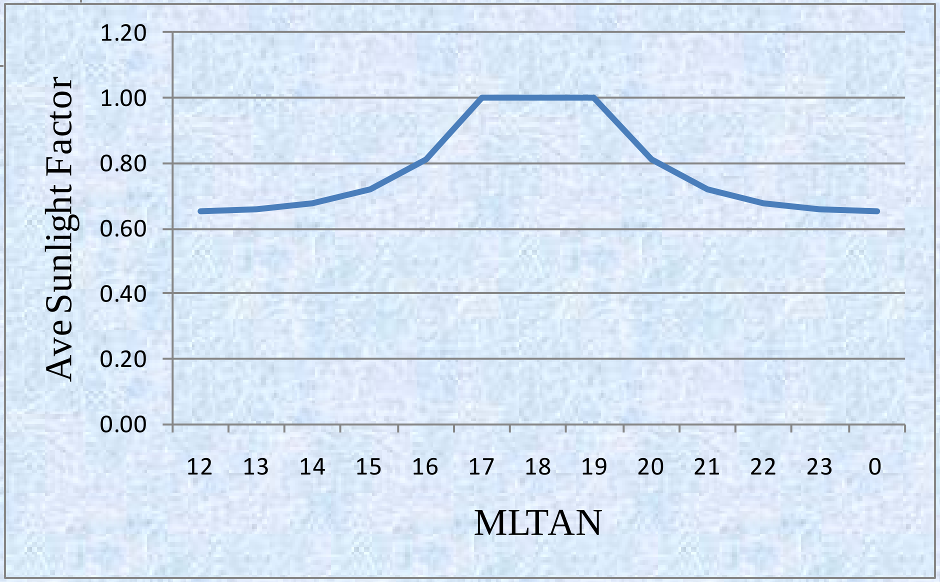
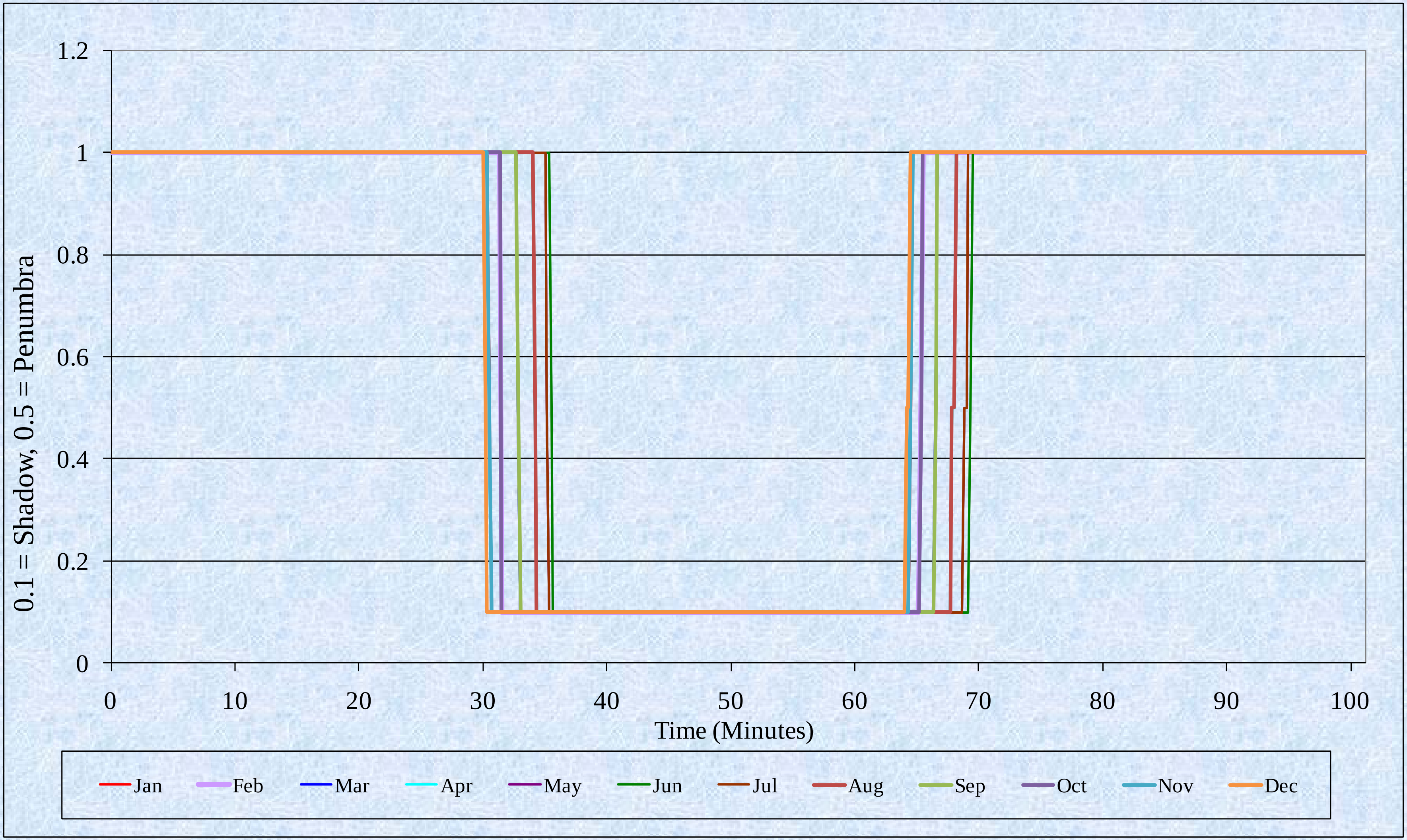




NPOESS MLTAN = 1330 or 1730

824 km
Orbit Period = 101.2 minutes
MLT of ascending node = 1330 (1:30 pm)
Vary Month (21st)



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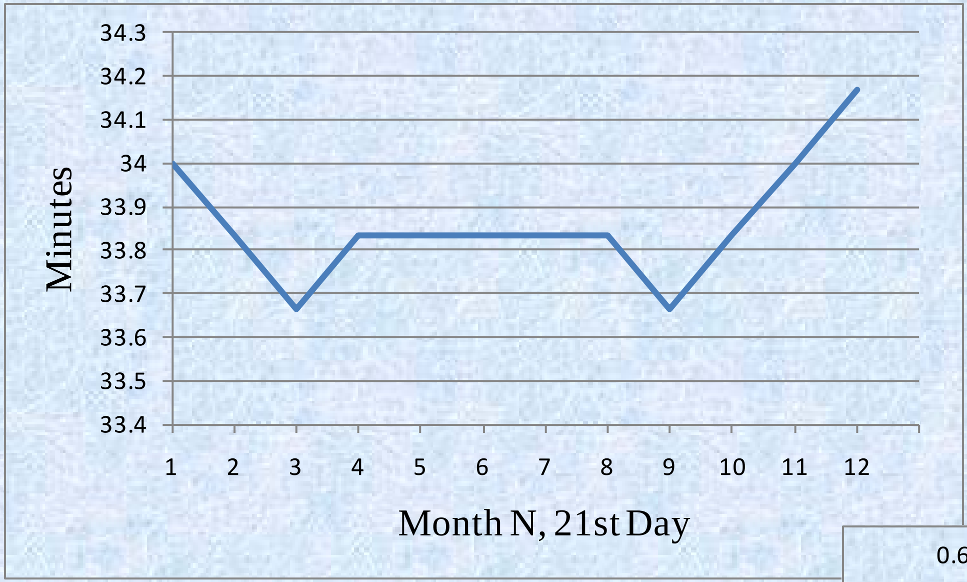

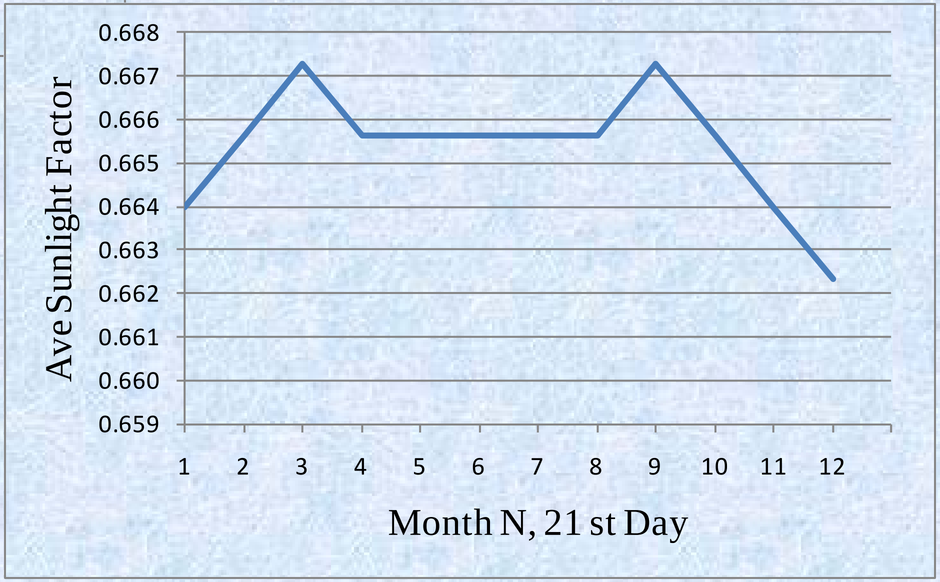

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824 km
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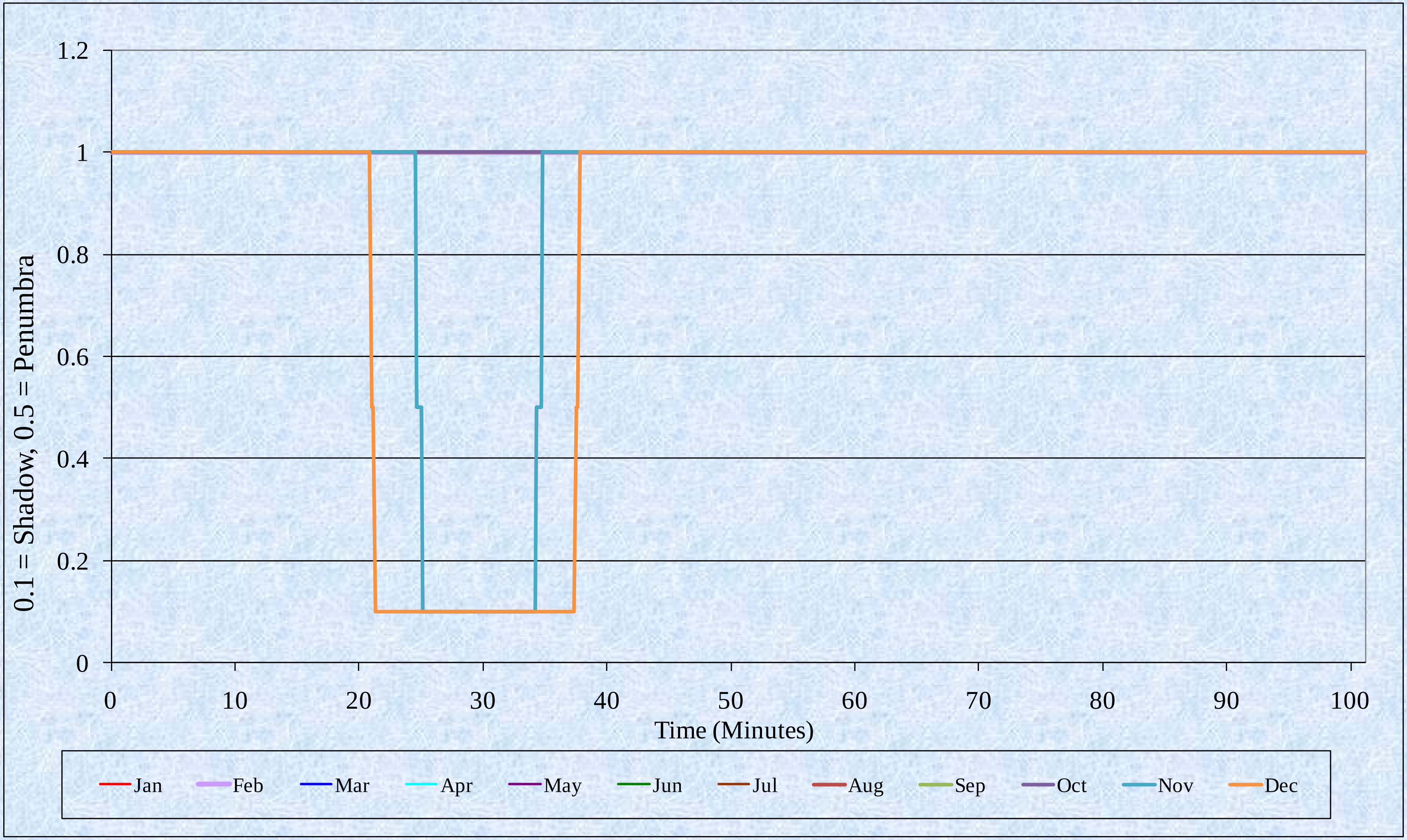
MLT of ascending node = 1730 (5:30 pm)
Vary Month (21st)



824 km
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MLT of ascending node = 1730 (5:30 pm)
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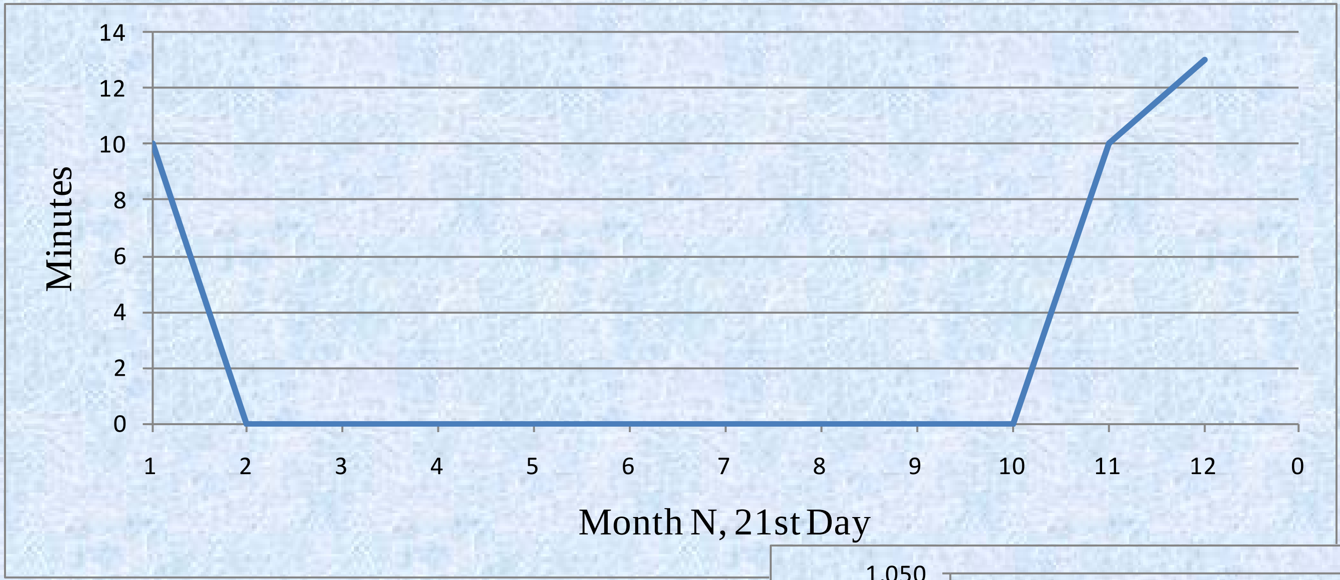
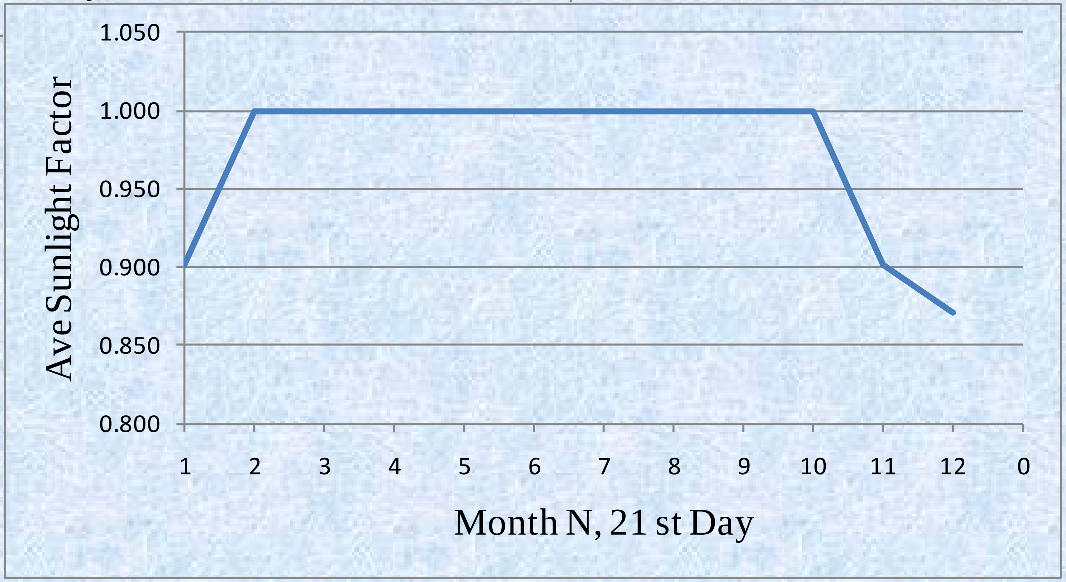


Minimum orbit average sunlight factor = 0.87



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Conclusions

- New excel tool allows quick examination of time in shadow for different orbit parameters
- Mission trades can include very important parameter of orbit average sunlight and electrical power